Title: MIXED SIGNAL SYNTHESIS
Inventors: Michael J. Demler
Application No.: 09/589,966
Filing Date: June 8, 2000
Docket No.: CADE-01016US0 Art Unit: 2128
Attorney: Karl F. Kenna Telephone No. (415) 362-3800

Mixed-Signal IC

Creating a Mixed-Signal World

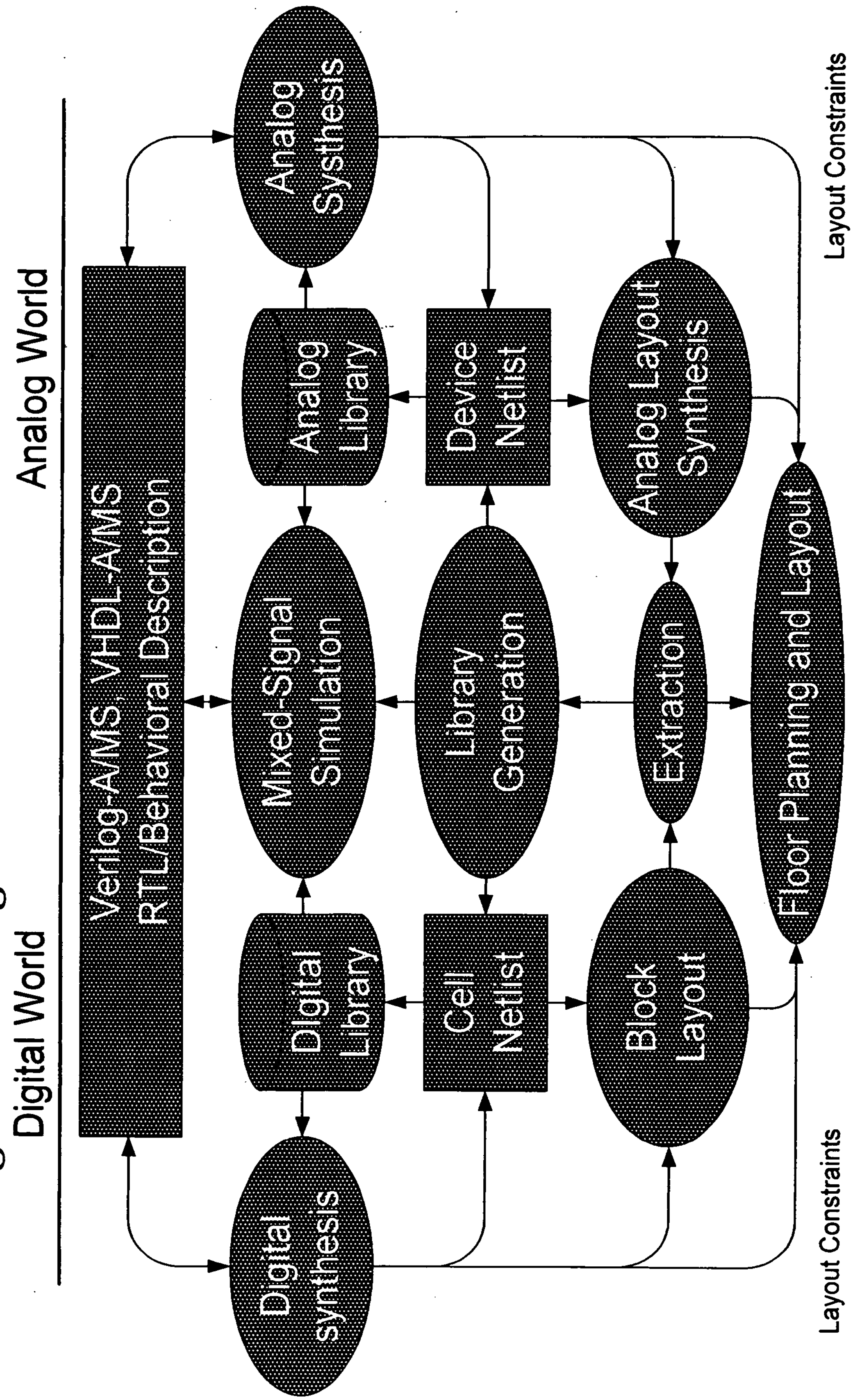

FIG. - 1A

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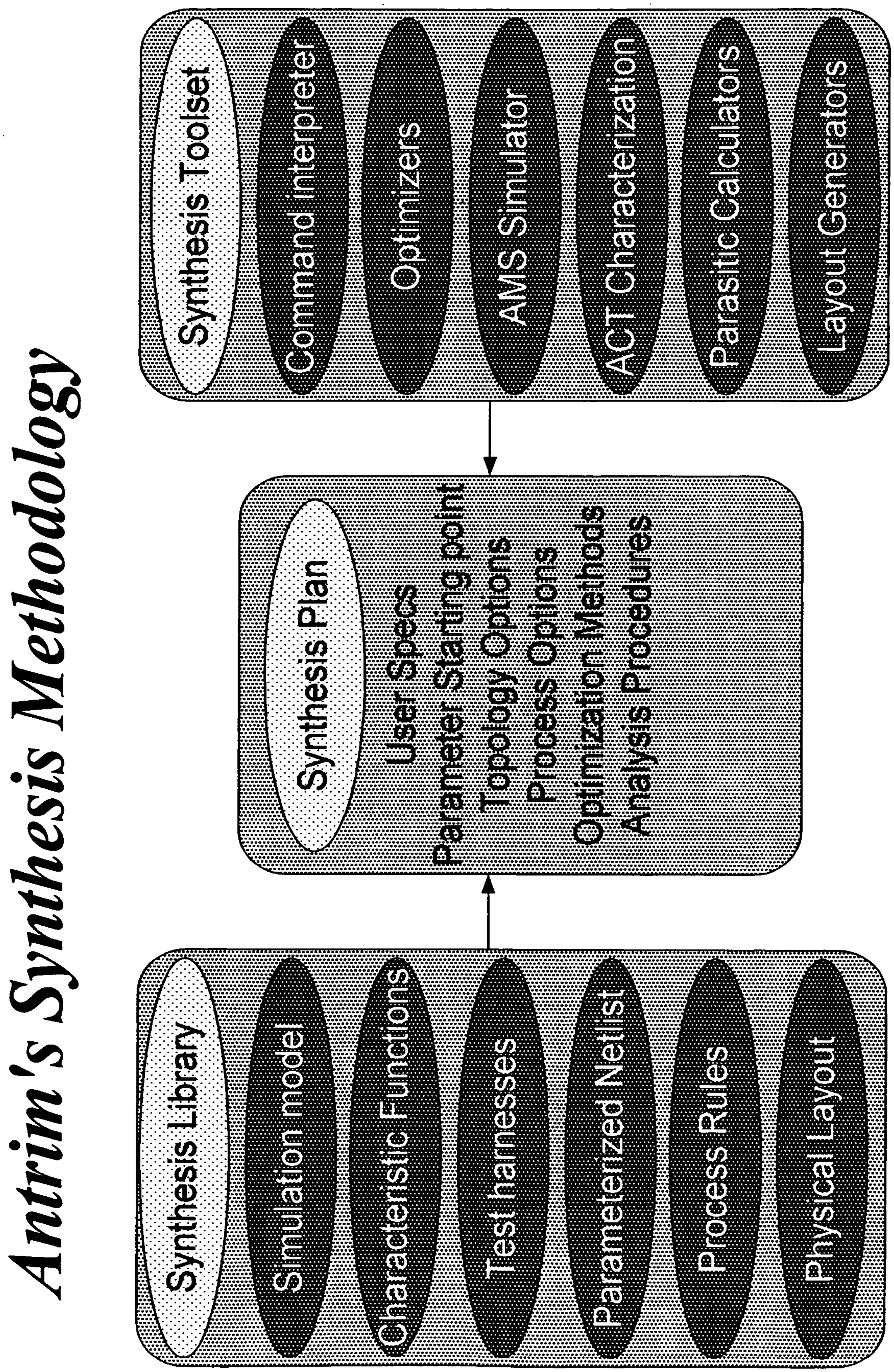

FIG. - 1B

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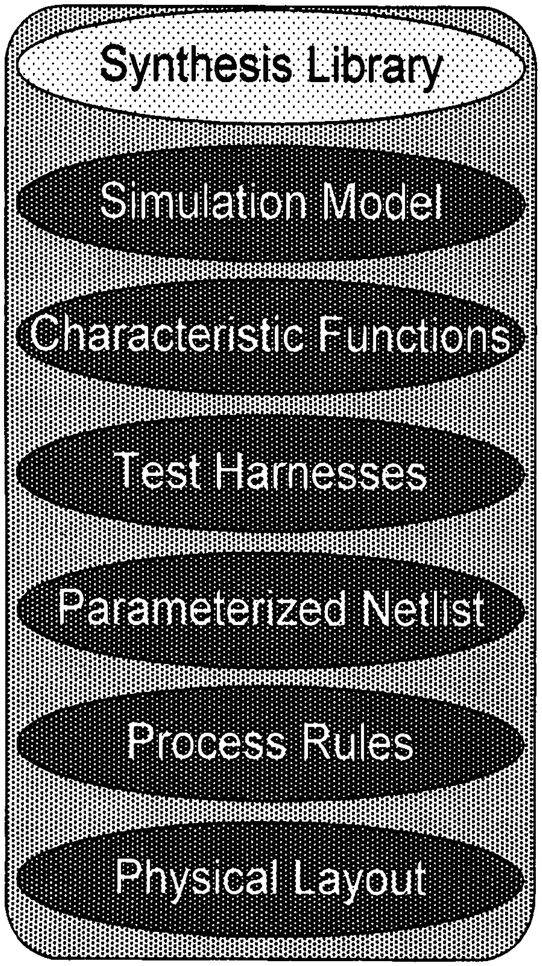
Major Components of Antrin-MSS

Synthesis Library



- Simulation models in Verilog-A/MS
  - represent library functions , parameterized to user's performance specifications
- Characteristic functions of design parameters
  - model circuit performance behavior during optimization
- Test harnesses and charaterization plans
  - developed with Antrim-ACT
- Netlists of mixed-signal functions
  - working circuits, parameterized for sizing to achieve user's performance specifications
- Process technology files - models and design rules
- Synthesizable layout cells

FIG. - 1C

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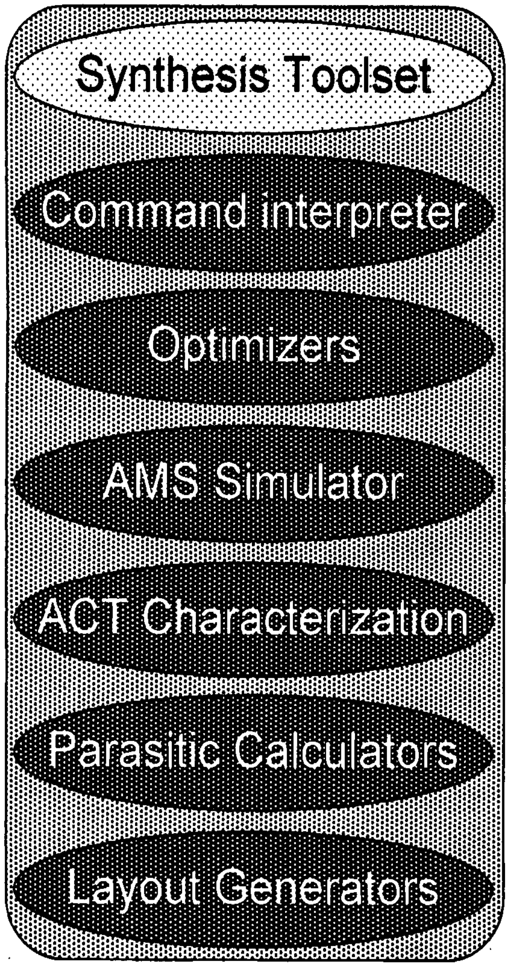
Major Components of Antrin-MSS

Synthesis Toolset



- Antrim-MSS Command Interpreter
  - extensions to Perl scripting language for synthesis plan execution
- Optimizers
  - toolkit of algorithms for sizing of design parameters
- Antrim-AMS
  - for simulation of characteristic functions, behavioral models and sized netlist
- Antrim-ACT
  - for development of characteristic functions, analytical models, test harnesses, circuit characterization
- Parasitic calculators
  - layout parasitic estimation from process rules and sized netlist
- Layout generators

FIG. - 1D

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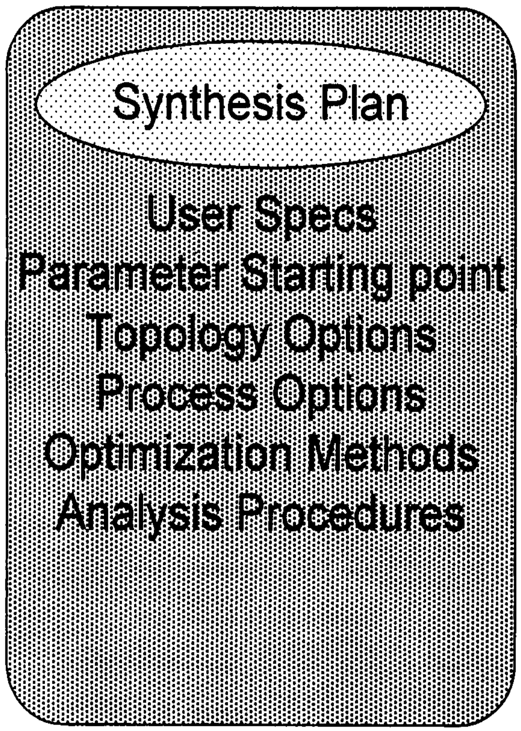
Major Components of Antrin-MSS

Synthesis Plans

- Blueprints for the sucessful synthesis of mixed-signal IP



- Developed by expert mixed-signal IC designers using MSS and ACT plan development tools
- Programmed series of steps for circuit partitionIng, model selection, sizing and optimization
- Specifications of design parameters to be used as optimization variables
- Specifications of performance characteristics to be used as optimization goals
- Steps for process retargeting
- Antrim-ACT characterization plan
  - Experiments
  - Test harnesses
  - Stimuli and other controls

FIG. - 1E

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Plan Author

Design Flow

- Design Partitioning
- Characterization
- Model Development
  - circuit
  - behavioral
  - analytic
- Setup Performance Parameters
  - measurements
  - test harnesses
- Set Design Parameters
- Define Optimization Steps

FIG. - 1F

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Plan User

Design Flow

- Select Function
- Specify Process
- Performance Specification
- Execute Plan
- Verification of Results

FIG. - 1G

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Antrim-MSS Architecture

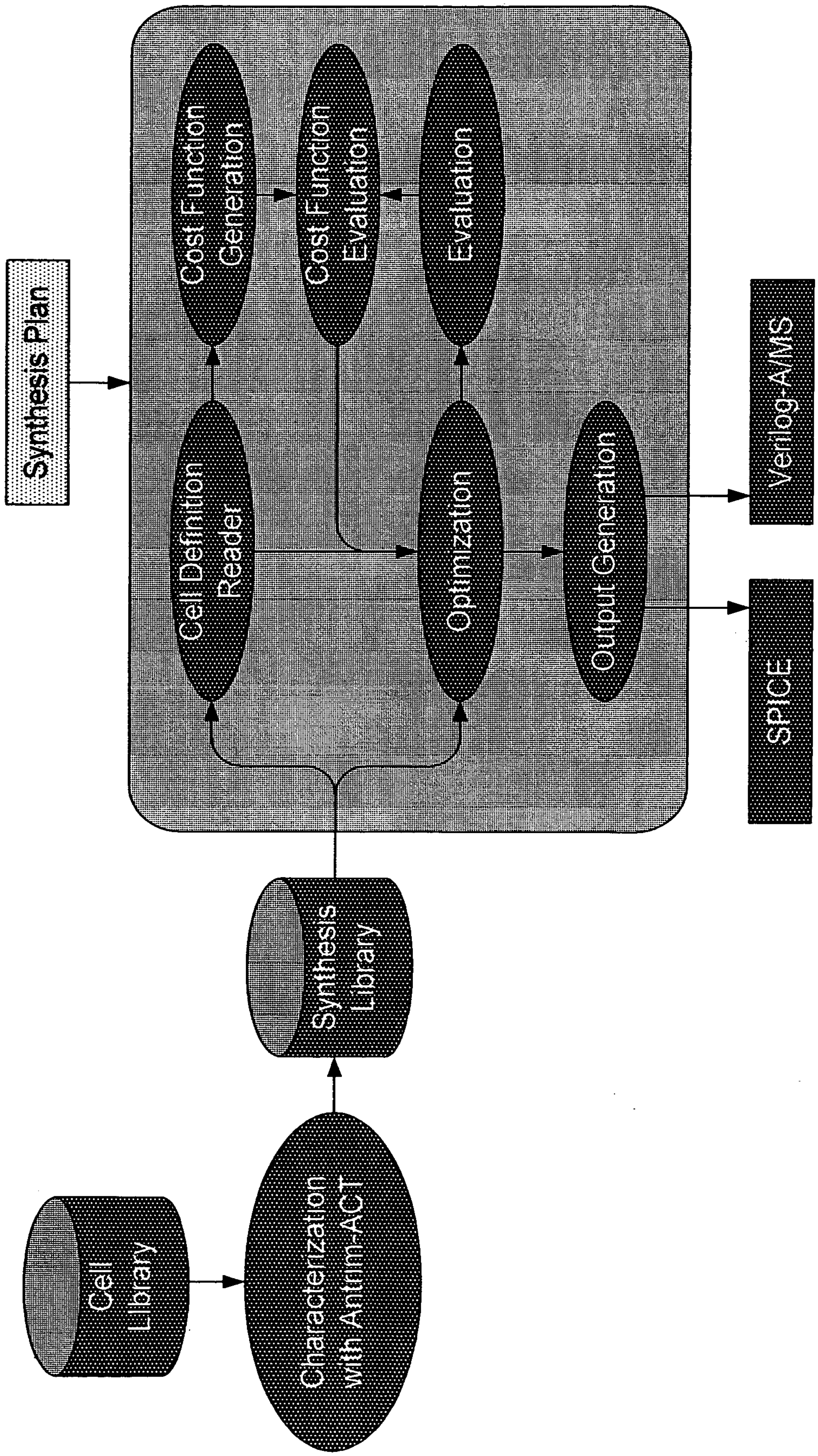

FIG. - 2

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Development of a Synthesizable VCO

- Circuit features:
  - Three cells: bias generator, differential delay cell, level restore
  - Eight delay stages for 100 MHz - 200 MHz operation
- Performance parameters:
  - power
  - center frequency
- Optimization plan:
  - size delay cell and bias circuit to achieve user's specifications

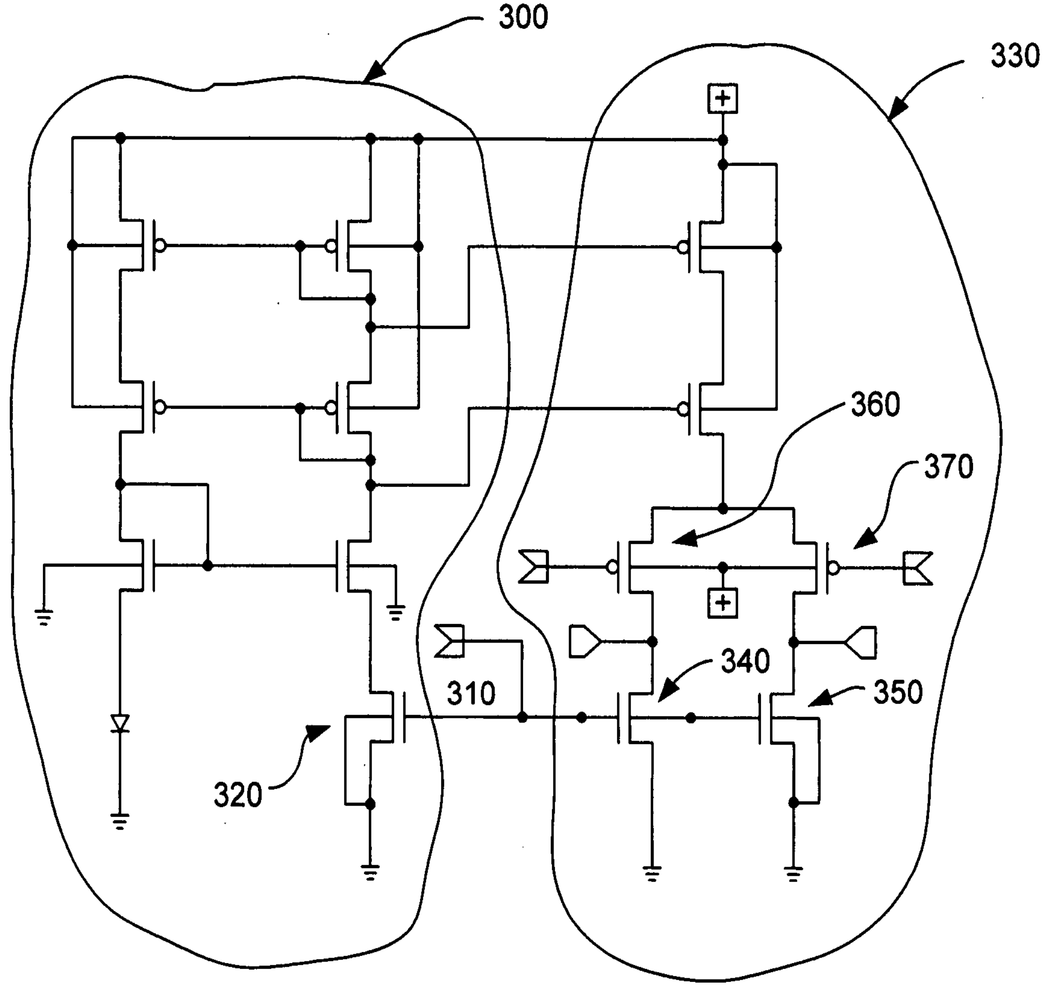

FIG. - 3

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Cost Function

- User-specified performance specs are formulated into a single cost function
- Optimization seeks a zero cost solution

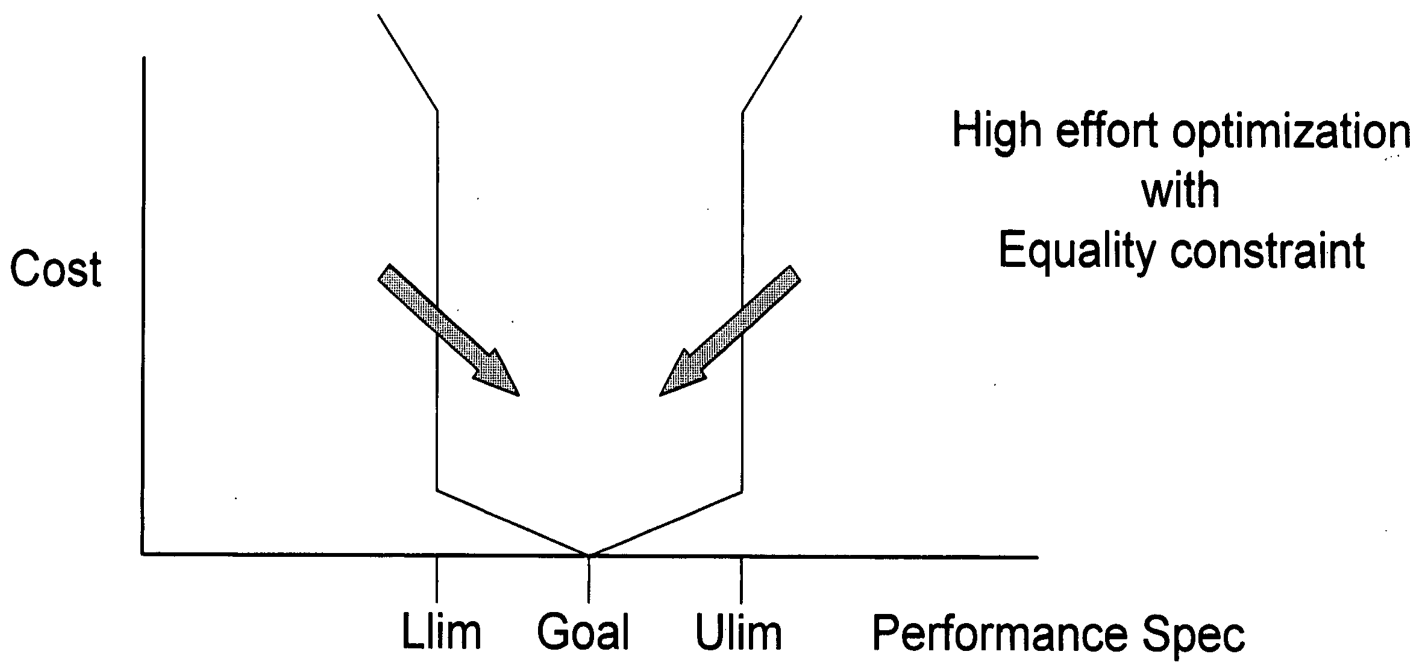

FIG. - 4A

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Cost Function

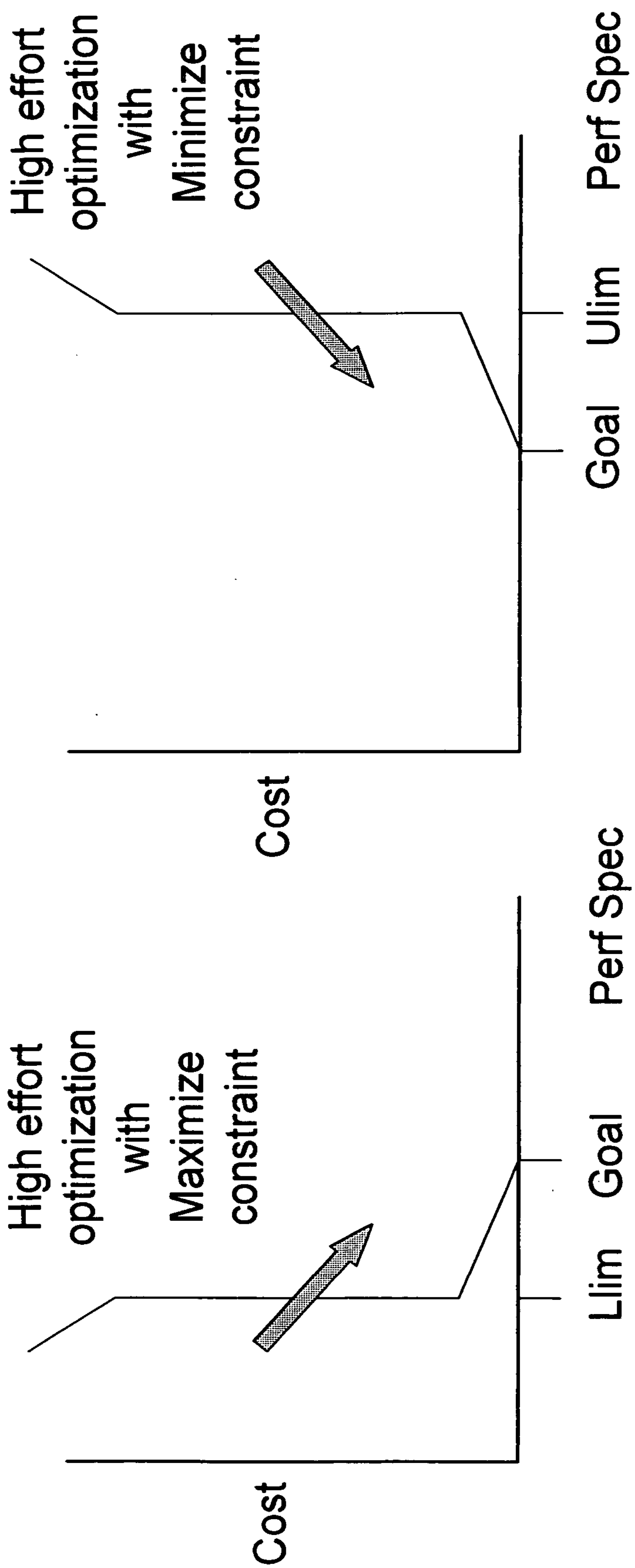

FIG. - 4B

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Cost Function

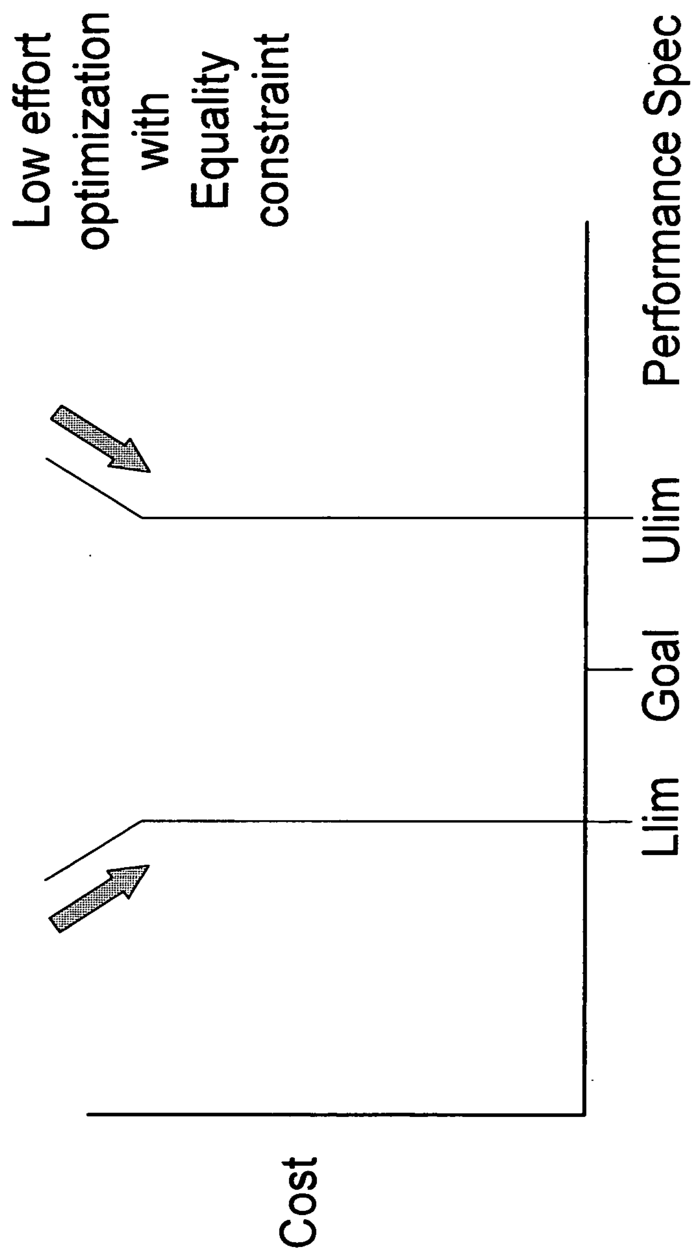

FIG. - 4C

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Cost Function

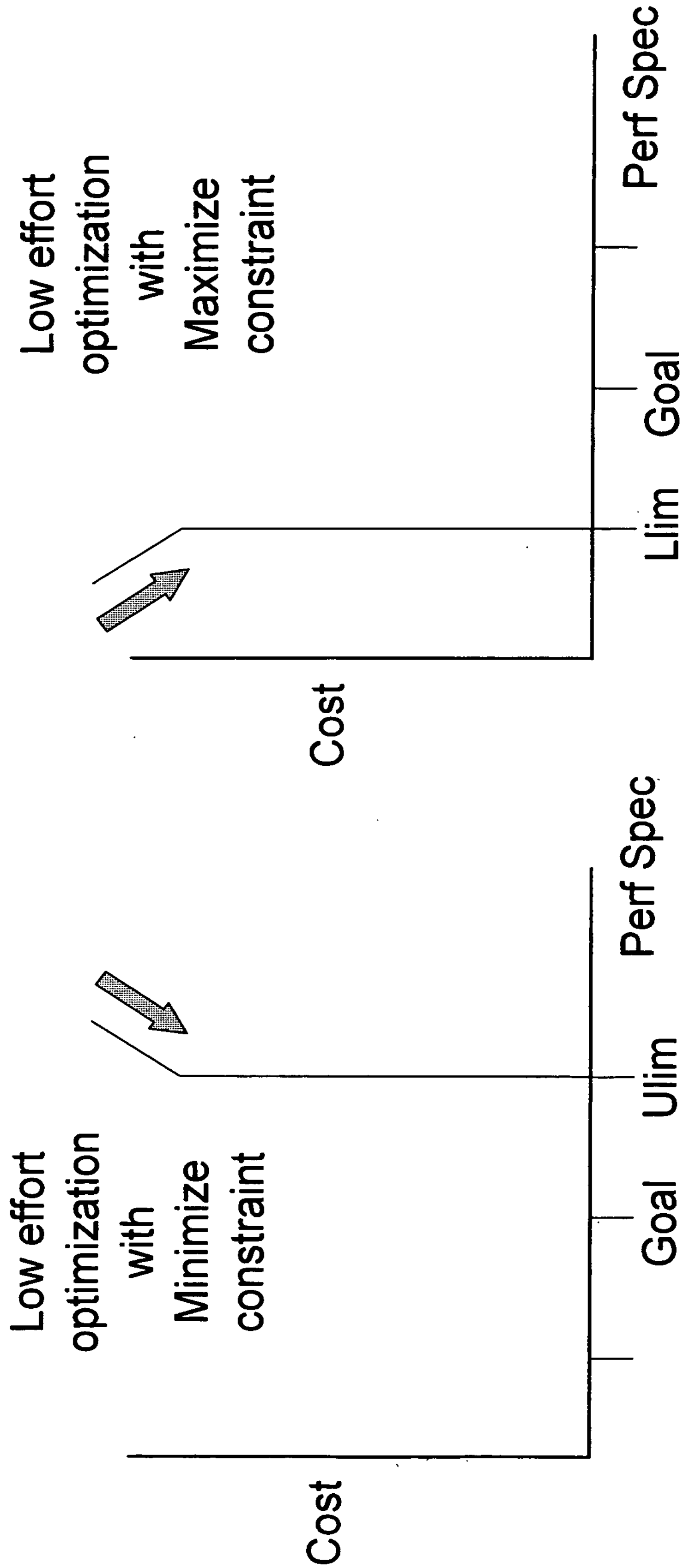

FIG. - 4D

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Example: Synthesis Plan for a VCO

Step One

- Size bias transistor for power specification
- 1st step - budget power according to user specification
  $P_{tot} = P_{bias} + 8 * P_{delay}$
- NMOS transistor must remain in triode region with $V_{ds} = V_{diode}$
- Minimize W_{bias} & L_{bias} to meet spec

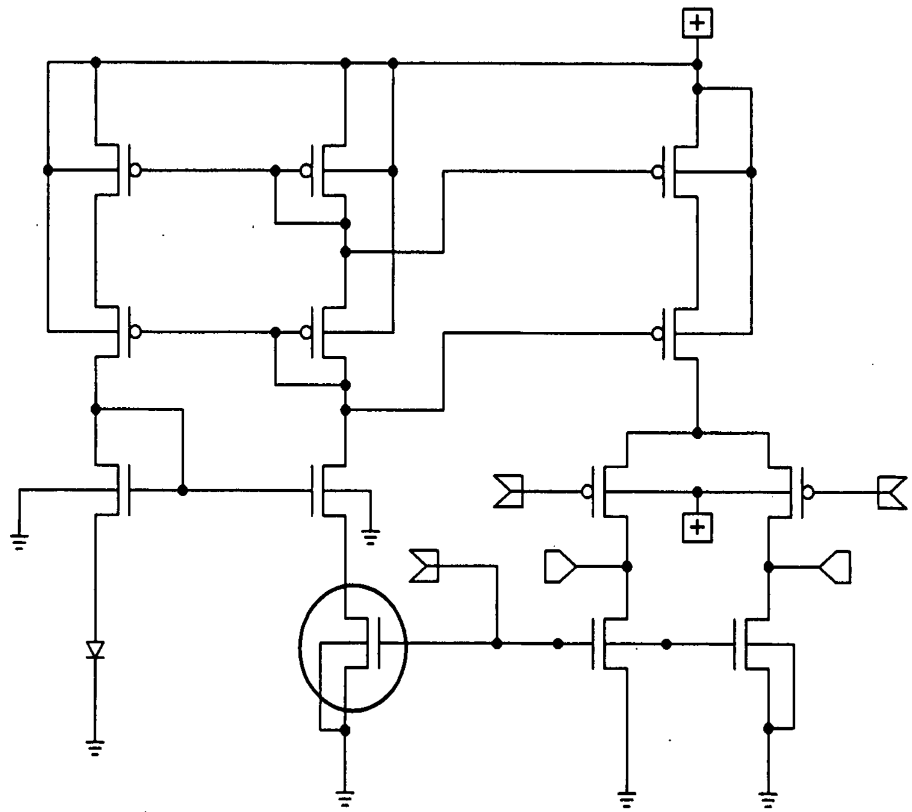

FIG. - 5

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Example: Synthesis Plan for a VCO

Step Two

- Mirror NMOS transistors from bias cell
- Size delay cell transistors for frequency spec
- Use behavioral model of F_0 vs. $W_{diff/}$, L_{diff}
- Minimize diff. pair for input load in ring oscillator
- Set L_{diff} to L_{min}
- Optimize W_{diff}

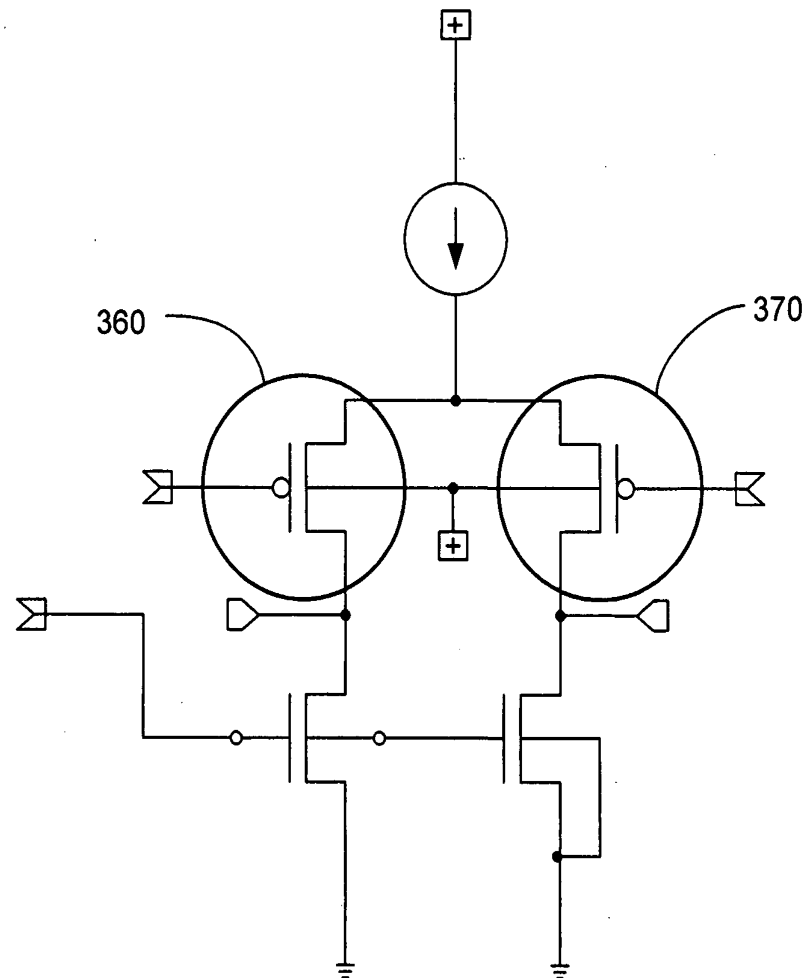

FIG. - 6

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Example: Synthesis Plan for a VCO

Step One

- Size bias transistor for power specification
- Measure current with condition $V_{ds} = V_{diode}$
- Minimize W_{bias} & L_{bias} to meet spec
- Analysis Setup:
  - simulate nbias_ivdc.v
    - test harness for bias current sizing
  - analysis = bias.tst
    - measurement experiment for current

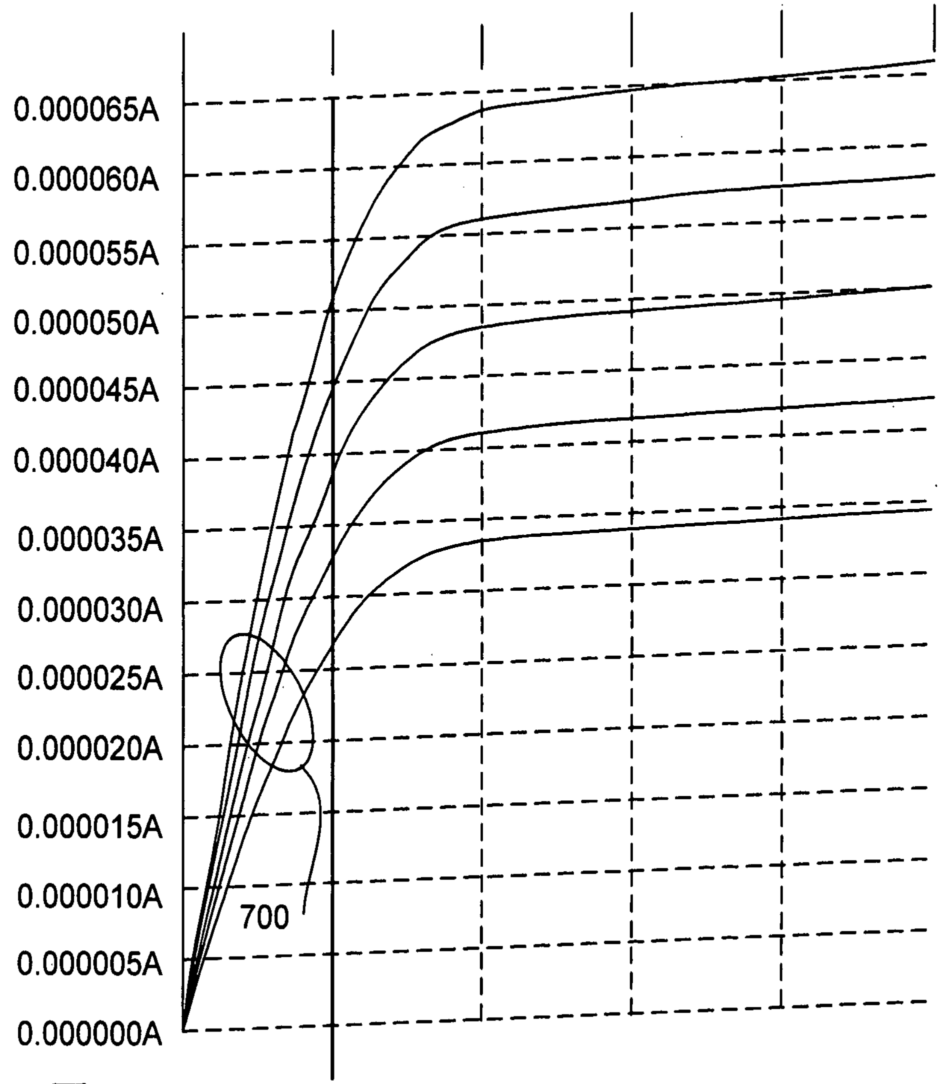

FIG. - 7

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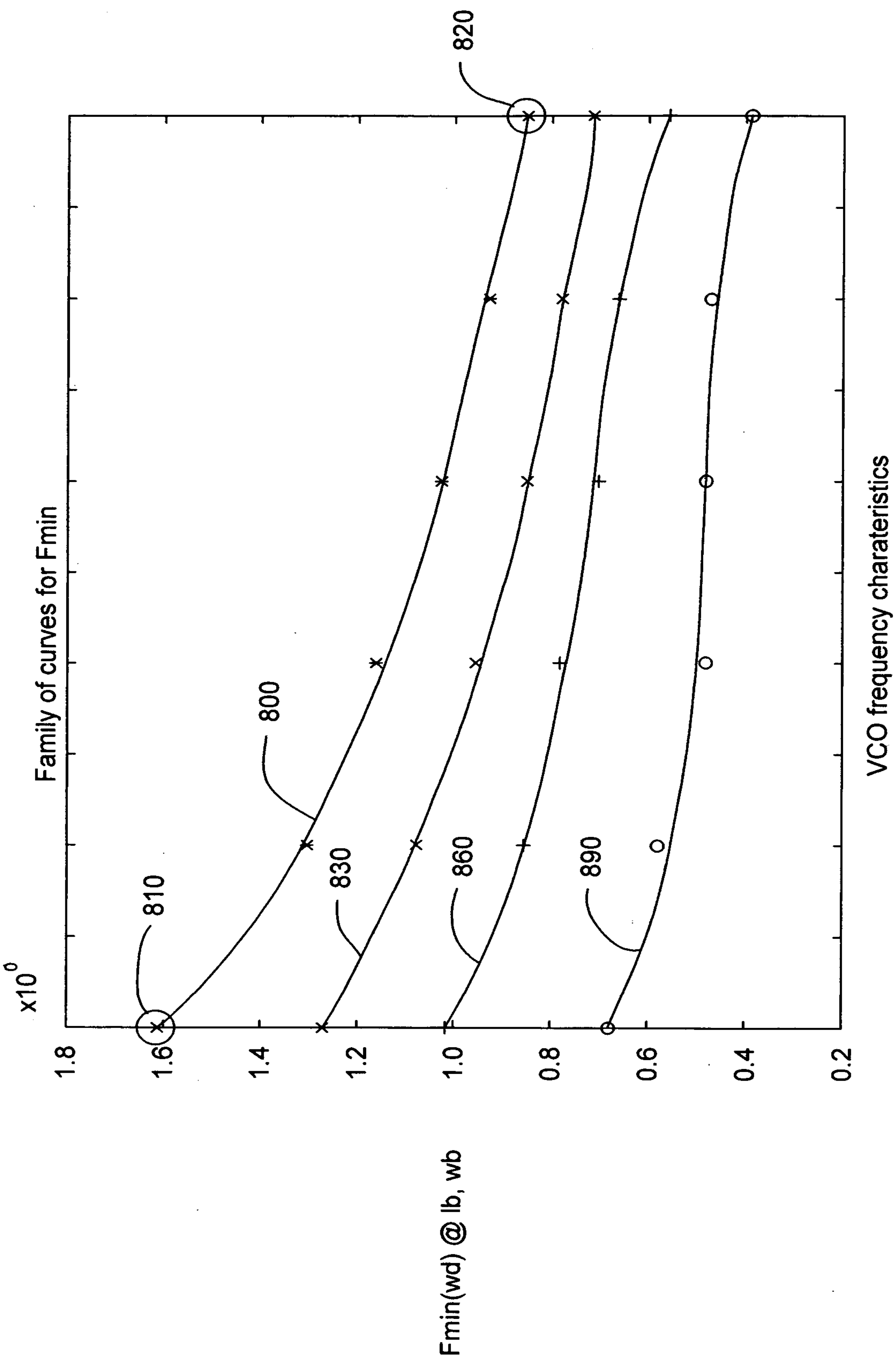

FIG. - 8

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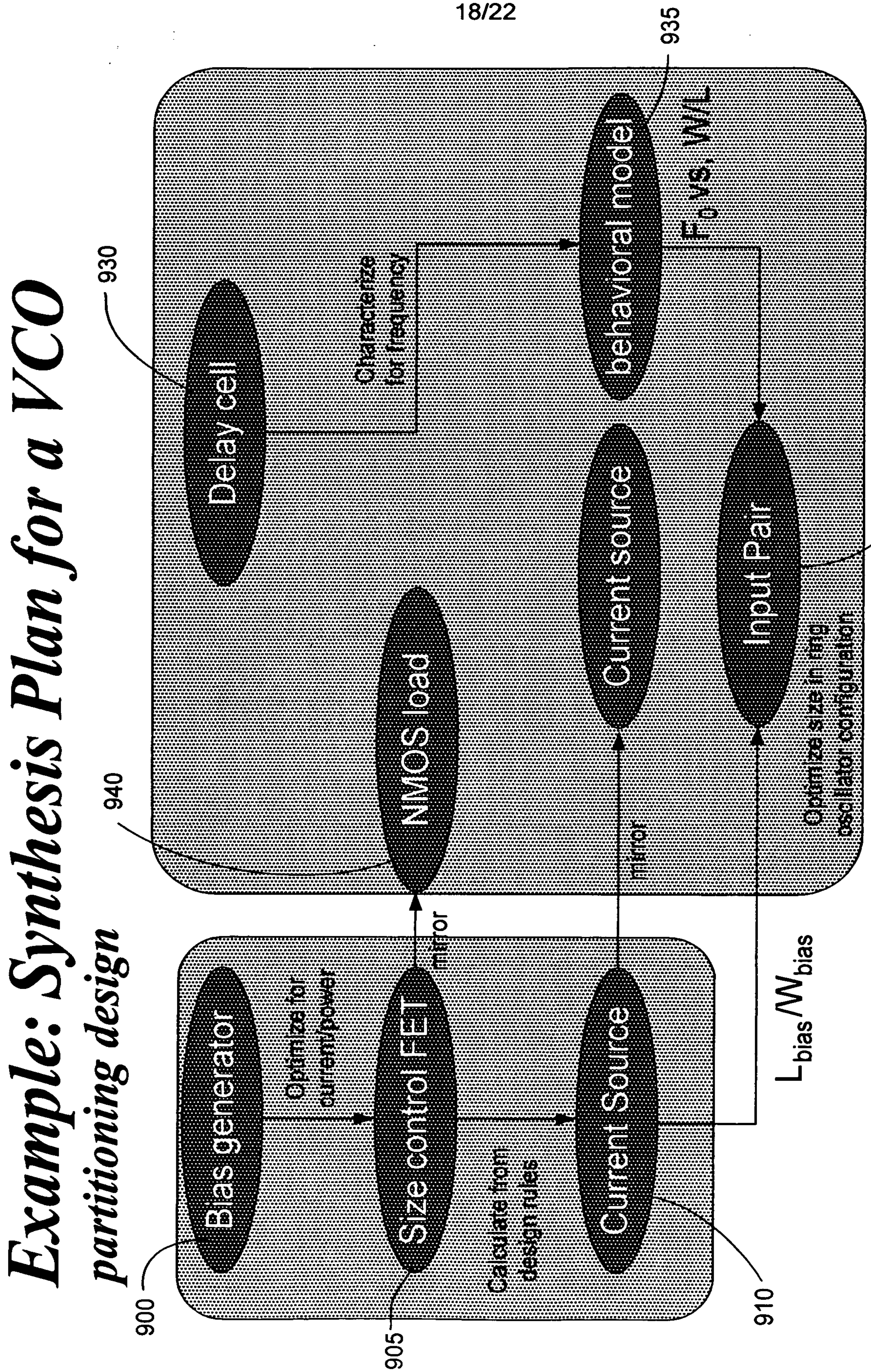

FIG. - 9

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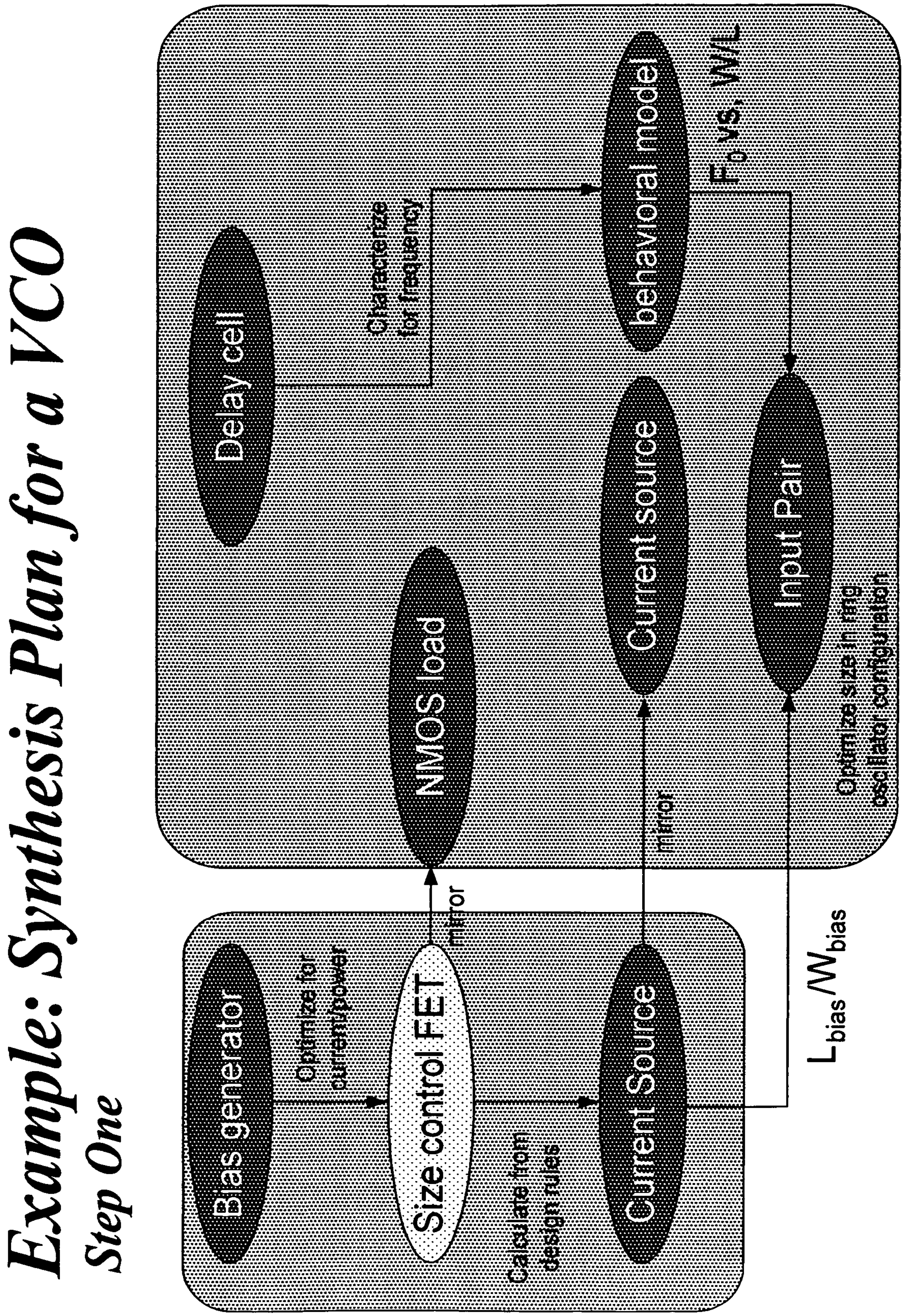

FIG. - 10

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Example: Synthesis Plan for a VCO

Step Two

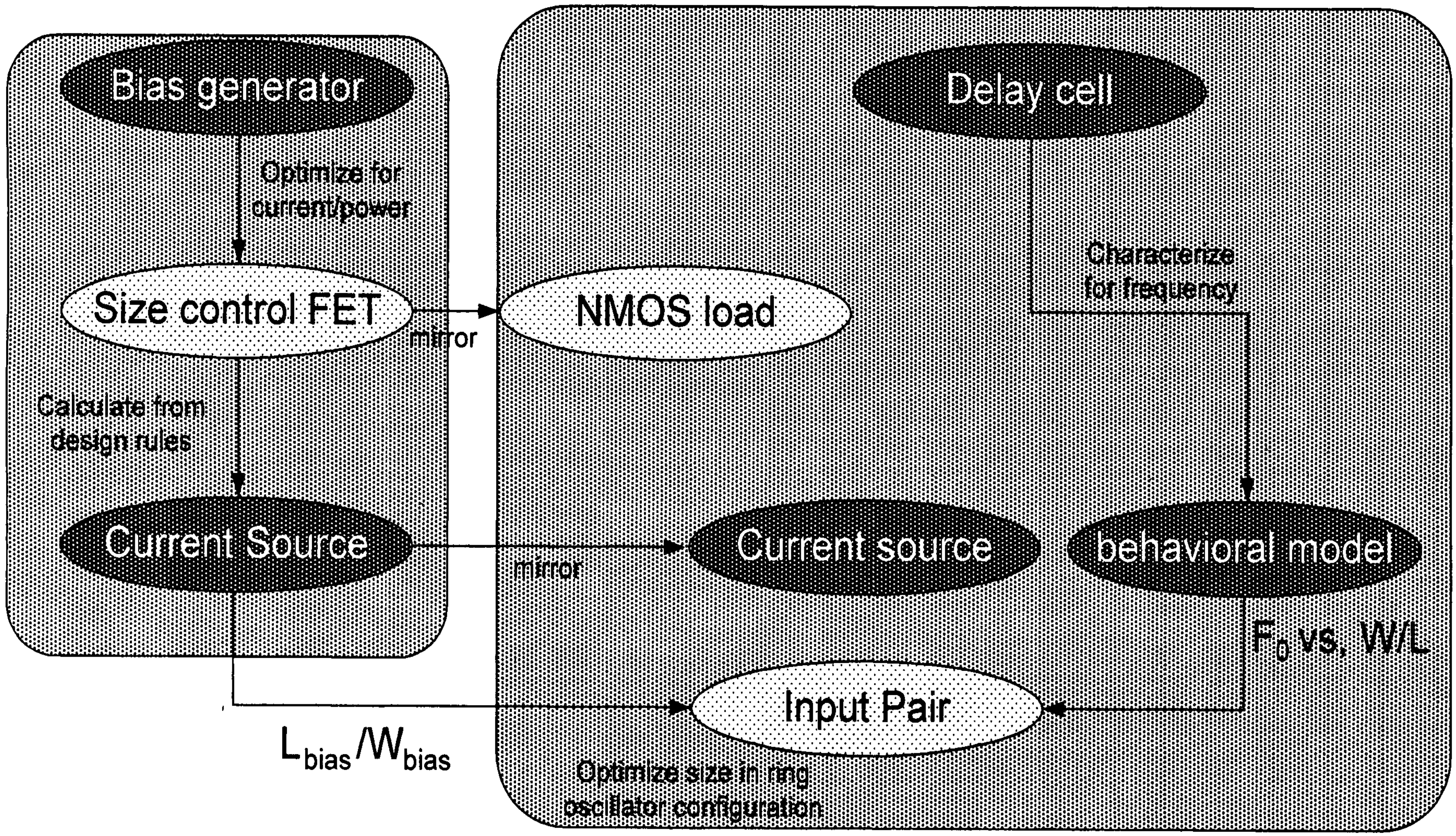

FIG. - 11

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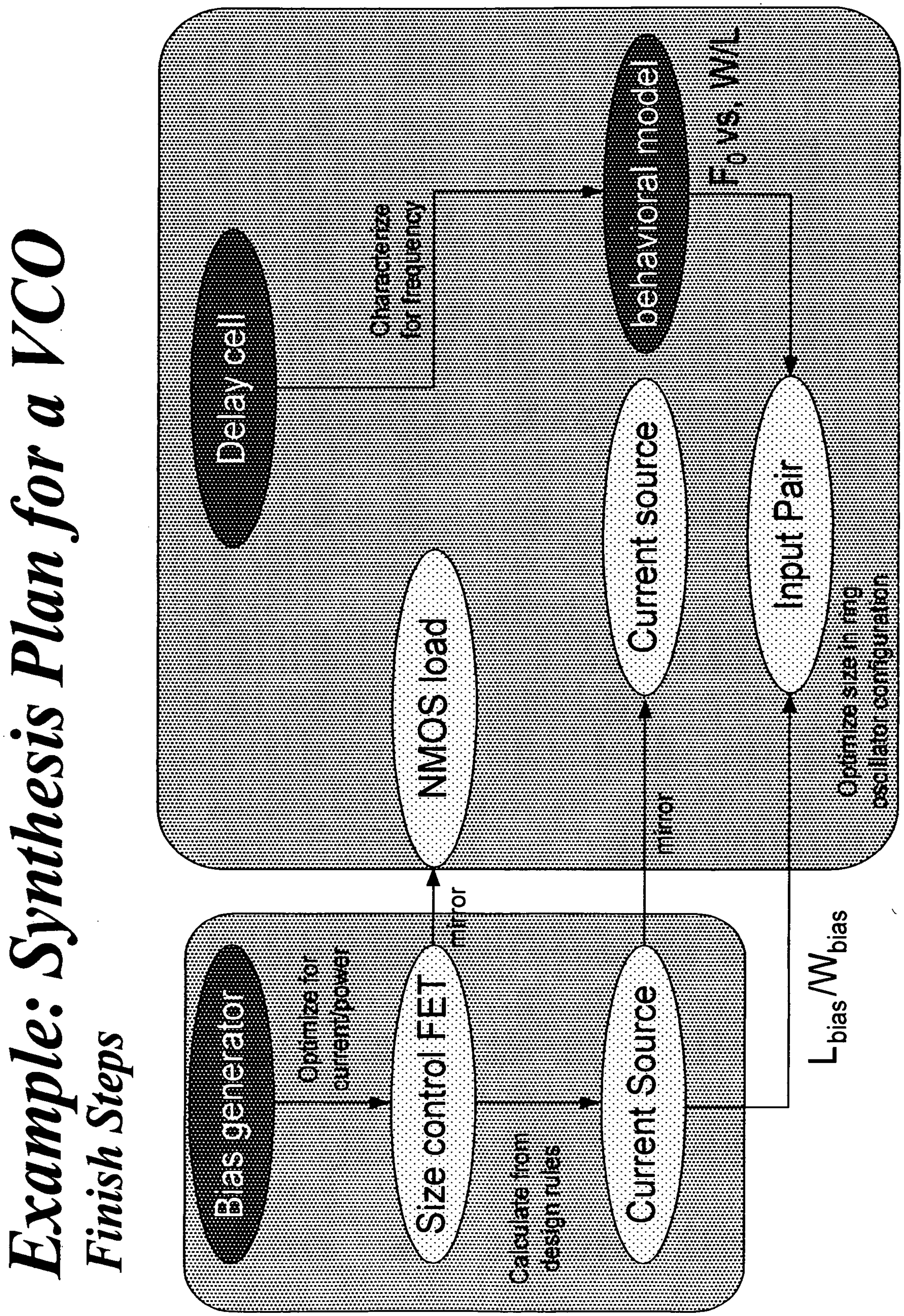

FIG. - 12

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Synthesis Plan for a VCO

Finish Steps

- Size noncritical MOSFETs in current sources
  - doesn't require optimization
- Synthesize level translator
- Verify complete design
- Could add other performance specifications
  - gain
  - F_{min}
  - F_{max}

FIG. - 13